EVAPORATION RECORDS FROM THE GULF COAST

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(WITH FOUR FIGURES)

In connection with field work in northern Florida, undertaken to determine the composition and limits of certain gulf coast forest associations and their relations in succession, and following the instructions of LIVINGSTON,[1] FULLER,[2] and the work of others in the north and west, records of the daily rate of evaporation in several of the typical plant associations were kept, some of them running through a period of 19 successive months. The Livingston rain-correcting atmometers were used and care was taken to follow the directions for their operation in all particulars. It was planned to visit each station once in two weeks, and this was carried out with few interruptions.

Station no. 1 was in an upland hammock forest on Norfolk Fine Sandy Loam. *Magnolia grandiflora*, *Fagus grandifolia caroliniana*, and *Acer floridanum* Pax (or *Acer saccharum floridanum* Sarg. Silva N. Am.) were the chief trees, with an undisturbed growth of young trees of these and other species and of mesophytic shrubs and herbs. The apparatus at this station suffered various mishaps, and the record is broken, but from January to May 1913, which includes the times of extreme minimum to maximum evaporation for all the stations (except that of *Pinus palustris*), the record is complete.

Station no. 2 was in an upland oak forest on Orangeburg Fine Sandy Loam, 2.5 miles west of Tallahassee. In this forest nine-tenths of the trees were deciduous, with *Quercus falcata*, *Q. stellata*, and *Carya alba* predominating. *Cornus florida* was common, but *Q. virginiana* and *Ilex opaca* (broad-leaved evergreens) were rare. *Myrica cerifera*, *Rhus copallina*, *Ilex vomitoria*, *Ceanothus americanus*, *Aralia spinosa*, *Vaccinium stamineum*, *Callicarpa americana*,

[1] LIVINGSTON, B. E., Evaporation and plant habitats. Plant World **11**:1–9. 1908; Operation of the porous cup atmometer. Plant World **13**:111–119. 1910.

[2] FULLER, G. D., Evaporation and plant succession. BOT. GAZ. **52**:193–208. 1911.

and *Viburnum rufidulum* were the principal shrubs about the station and made a rather close shrubbery throughout the woods. The list of herbs shows nothing especially distinctive in the way of species, as they are practically the same as those of the beech and short-leaved pine forests in which stations 3 and 4 were located.

Station no. 3 was in an upland short-leaved pine forest about 1 mile north of Tallahassee, on Orangeburg Sand. The mature trees were almost entirely *Pinus echinata*, but this wood was well advanced in the undergrowth toward the oak-hickory stage; the young half-grown trees of *Quercus falcata*, *Q. stellata*, and *Carya alba*, and also of *Q. virginiana* and some *Fagus grandifolia caroliniana*, made one story, under which was a lower growth of *Quercus nigra*, *Q. laurifolia*, *Q. marilandica*, *Crataegus* spp., *Prunus angustifolia*, *Cornus florida*, *Nyssa sylvatica*, *Vaccinium arboreum*, *Callicarpa americana*, and *Viburnum rufidulum*, with numerous lianas as *Smilax glauca*, *S. pseudo-china*, *Cissus* spp., *Vitis rotundifolia*, *Gelsemium sempervirens*, and *Lonicera sempervirens*. Common herbs of the station vicinity were *Arisaema Dracontium*, *Oenothera biennis*, *Sanicula canadensis*, *Gerardia purpurea*, *Mitchella repens*, *Eupatorium album*, and *Chrysopsis mariana*.

Stations 2 and 3 were operated for 19 months continuously without a break or mishap.

Station no. 4 was in a beech wood about one-fourth of a mile east of the station in the pine forest. To the west and south of this forest was a short-leaved pine wood in a still later stage than the one in which station 3 was placed. The proportion of deciduous trees was larger and the trees older, while the undergrowth was much less dense, which may largely be accounted for by the fact that this wood had been stocked with hogs and cattle for some years. To the north its character changed quite abruptly, the pines being few and the number of mature deciduous trees not large, but the undergrowth was very dense. Throughout this wood (an area of some 40 acres) were scattered beeches of all ages. Magnolias were less common. The beech opening in which the station was located apparently had once been somewhat swampy, although but little lower than the rest of the ground and scarcely wetter except after heavy rainfalls. As a whole the forest was level and formed part of

a level hilltop. The soil was mainly Orangeburg Sand, which is a transitional type between the Orangeburg and Norfolk Fine Sandy Loams, and which, as stated in the soil survey, is occasionally found in small isolated patches within the Orangeburg Loam areas, occupying slight elevations which have not suffered from erosion.

The evaporimeter was placed in the portion of the woods freest from shrubs or undergrowth of any kind, there being comparatively few herbs in the vicinity, those noted being mainly the same as those of the open pine wood, except that the fireweed (*Erechtites hieracifolia*) was common. This station suffered several interruptions during the 18 months of its operation, owing to the pasturing animals and other causes.

The four stations described were all on the hills or elevations over 100 ft. above sea level, and none of them suffered from frost.

Station no. 5 was established in September 1912, about 5 miles southwest of Tallahassee, on low sandhill soil, a strip of gently rolling yellowish sand, covered with a dense growth of scrub oaks, only an insignificant part being under cultivation. It has doubtless been a shoal, extending east and west parallel with the edges of the abrupt upland to the north which once formed the shore line. This sandhill area is characterized everywhere by a very definite as well as limited tree flora. There are 3 scrub oaks and 2 pines, the latter being scattered. *Quercus catesbaea*, *Q. margaretta*, *Q. cinerea*, and the long-leaved pines, *Pinus palustris* and *P. caribaea*, are the species. The chief undershrubs near the station were *Asimina pygmaea*, *Vaccinium arboreum*, and *V. corymbosum*. *Ascyrum hypericoides* was also noted at this station and appears to be generally ubiquitous, although frequent rather than abundant. The herbs were *Asclepias tuberosa*, *Scutellaria integrifolia*, *Gerardia purpurea*, *Eupatorium aromaticum*, and *Liatris laevigatus*. Although the sandhill region is very sparsely inhabited, the records from this station happened to be frequently interrupted by meddlesome hunters as well as by fire, frost, and a cyclone. In the effort to keep the apparatus hidden it was twice moved. The cup was broken by frost on November 28, 1913.

Station no. 6 was in a long-leaved pine forest on Norfolk Sand, 4 miles southwest of Tallahassee and a quarter of a mile north of

station no 4. At this station the evaporimeter was broken by frost once in the second winter of its history, on January 11; it was shot to pieces once; and was once in the immediate path of a June cyclone which blew down most of the trees in a track 800 ft. wide. By this storm the cup was demolished but the reservoir was unbroken. The location was then changed a few rods to the east. This station was peculiar in that the trees were essentially like those of the Leon Sand station (no. 7) near Lake Jackson, and the herbaceous plants like those on the sandhill soil. At the outer border of this soil, where the Norfolk Sand and the sandhill join, the scrub oaks gave way abruptly, the line between the two soils being generally as sharp as if the planting had been artificial.

The Leon Sand station, no. 7, was in operation more or less continuously for 18 months, being broken by frost once the first winter and twice during the second winter; it was also once in the path of a fire. This Leon Sand is situated 9 miles northwest of Tallahassee, being a strip of long-leaved pine forest about 200 yards wide. This small area is bordered on the north by a slough which is directly bordered by Norfolk Sand, and to the south the soil is the Norfolk Fine Sand, each with characteristic vegetation. This strip of the Leon Sand is an outlying neck of a larger area of the same soil 2.5 miles wide and 1 mile long, the only area of this particular soil in the northern part of the county which is accessible to the railroad. However, in its growth it is typical of the larger area of the flatwoods to the southeast. This soil, wherever it occurs, is very level and poorly drained and therefore excessively wet a large part of the year. Station no. 7, therefore, was on the wettest soil of any, and its vegetation should be compared with that of station no. 6, which also supported a long-leaved pine forest on the Norfolk Sand, one of the driest soils of the region. The wood on the Leon Sand was very open and the destruction caused by turpentining had still further thinned it. Owing partly to frequent fires and partly to the general quality of the soil and the drainage, the undershrubs were very low, seldom exceeding 2 ft. in height. The forest floor was sparsely covered with wire grasses. Apart from the pines, the trees noted about this station were occasional small specimens of deciduous trees, as *Quercus falcata*, *Q. virginiana*, *Q.*

nigra, *Liquidamber styraciflua*, *Acer rubrum tridens*, and *Nyssa sylvatica biflora*. The undershrubs were *Quercus myrtifolia*, *Q. minima*, *Pyrus arbutifolia*, *Rubus villosus*, *Rhus copallina*, *Ilex glabra*, *I. lucida*, *Hypericum fasciculatum*, *Vaccinium virgatum tenellum*, *Viburnum nudum*, and *V. molle*. A common liana was *Gelsemium sempervirens*, but the most common plant of all was *Serenoa serrulata* (saw palmetto). The herbs about this station make a distinctive list, the majority being species of Compositae, as *Helianthus angustifolius*, *Rudbeckia laciniata*, *Aster Tradescanti*, *Solidago fistulosa*, and *Bidens bipinnata;* there were also *Polygala lutea*, *Viola lanceolata*, *Sabatia gracilis*, *S. lanceolata*, *Pinguicula lutea*, and *Valerianella radiata*.

Stations no. 8 and no. 9 were located in October 1913 in the meadow of the Ocklocknee River. One was placed in a willow growth on the south bank, the apparatus being located in the outer border of the narrow strip of trees edging the stream and 5 or 6 ft. above the water at its normal stages. At this point a strip of bare sand, 15–20 ft. wide, separated the willows from a birch zone. Immediately bordering the river this meadow strip was about one-fifth of a mile wide, bounded on the east by a strip of Norfolk Sand with the long-leaved pines. The area occupied by the willows was subject to frequent overflow and no other plants seemed able to maintain themselves permanently in this zone. The growth here was not luxuriant, few of the trees exceeding a height of 10 or 12 ft. The records from these stations were interrupted by frost about December 21, 1913, and again on January 18, 1914, while from February 1 to March 28 the apparatus was covered by water two-thirds of the time and no records were secured. The birch station, 4 ft. higher and 15–20 ft. farther inland than the willow station, suffered similar interruption, except that the interval due to the flood was two weeks shorter and the apparatus was reestablished March 15, at which time the willow station was still completely under water. On the whole, the growth here was more luxuriant, although few of the trees had trunk diameters greater than 6 inches, or height greater than 15–20 ft.

Laboratory examination of each of the soils at the several stations was made to determine the organic content and general

character. The Orangeburg Fine Sandy Loam soil from the Spanish oak-post oak station, when dried, was a dark brownish gray. It is an excellent soil, rich in humus, and the drainage in the locality of the station was good. The soil from the short-leaved pine station was a medium brownish gray, similar to the preceding but containing a larger proportion of sand (Orangeburg Sand), and less humus. The soil from the beech wood was the same according to the classification of the United States Soil Survey Report, and it resembled that of the pine wood in the samples taken in the course of this study, but both soil and subsoil were of a brighter reddish tinge. The area of the beech station was hardly so well drained as that of the pine wood. The soil from the *Pinus palustris* forest on Norfolk Sand was very similar in color (both soil and subsoil) to that of the short-leaved pine, but contained decidedly less clay, separating in loose grains when dry, while the other dried in small lumps. It was also less rich in humus. The drainage was excellent to excessive. The soil from the scrub oak forest (which adjoined the preceding on the south) was very similar to Norfolk Sand in texture but a brighter red and perceptibly poorer in humus. The soil from the Leon Sand station was a medium gray sand with a very small admixture of organic materials. It was too wet for agricultural crops.

The evaporation records from the mesophytic forest (station no. 1), during the time it was steadily running, showed a consistently lower average and actual rate than any other station. The minimum monthly rate for this station was 6.05 cc. per day in January. The actual minimum was 4.5 cc. in January. The maximum monthly rate was 10.27 cc. daily in April, and the actual maximum was 11.9 cc. the first of May. The mean average rate for the 4 months covering the time from the minimum to the maximum was 8.5 cc. per day, an interesting result in comparison with the record of evaporation for beech-maple forests in the north.

Station no. 2, the Spanish oak-post oak forest, in comparison, gave a record of 9.90 cc. per day for the same period of the same year. The average of this station for 18 months' continuous and unbroken record, however, is 14 cc. daily. The minimum monthly

average is 9.94 cc. per day in December, and the maximum monthly average is 22.20 cc. daily in April. The actual minimum during the 18 months was 7.01 cc. in October, and the actual maximum was 29.28 cc. in March.

The short-leaved pine station, no. 3, averaged 11.67 cc. per day for the same period of the same year as given for stations nos. 1 and 2; and for an 18 months' unbroken record, 14.22 cc. per day. The minimum monthly average was 8.83 cc. per day in January, and the maximum monthly rate 19.7 cc. daily in April. The actual minimum was 5.18 cc. in January, and the actual maximum was 25.04 cc. in May. Comparison of stations 2 and 3 thus shows the averages as based on the yearly rate to be very similar. If, however, a comparison be made of their rates during the two general periods for deciduous trees, namely, with full foliage and without full foliage, or summer and winter (from June to November, and from November to June), the comparison shows that the June to November season gave a rate of 12.49 cc. daily for the oak forest, and of 13.8 cc. daily for the pine forest; while the winter rates (November to June) were, respectively, 15.69 cc. and 13.70 cc. This demonstrates a greater evaporation in winter in the deciduous forest, and the greater evaporation in summer from the pine forest. However, the similarity in the yearly rate, covering as it does the extremes of the two years, shows that the evaporation in the two forests was not greatly different, and this may seem related to the fact that at both stations there was an abundance of shrubbery of similar composition; if anything, that of the pine wood, being in two stories, was the thicker, and the telescoping of these two associations was conspicuous.

The beech forest, which had been burned and pastured, gave an average result of 16.63 cc. daily for the whole period of 18 months (with one break in the record for November to December 1912), an average of 11.21 cc. per day for the period from January 1 to May 1, 1913, and an average of 13.4 cc. for the summer (full foliage) period. This last compares with the same average of the pine wood, showing a similarity between the pine forest and the pastured beech wood. June shows the minimum monthly rate for this forest, and March the maximum (fig. 1).

Station no. 5, that of the scrub oaks, gave 15.52 cc. daily for 18 months, and 15.30 cc. daily for the period from January to May 1913. For the summer (June to November) the average was 13.95 cc. daily, corresponding to the short-leaved pine and the pastured beech wood. The winter rate was 14.1 cc., intermediate between that of the oaks and pine. The period of greatest evaporation was April; while December, January, and February showed

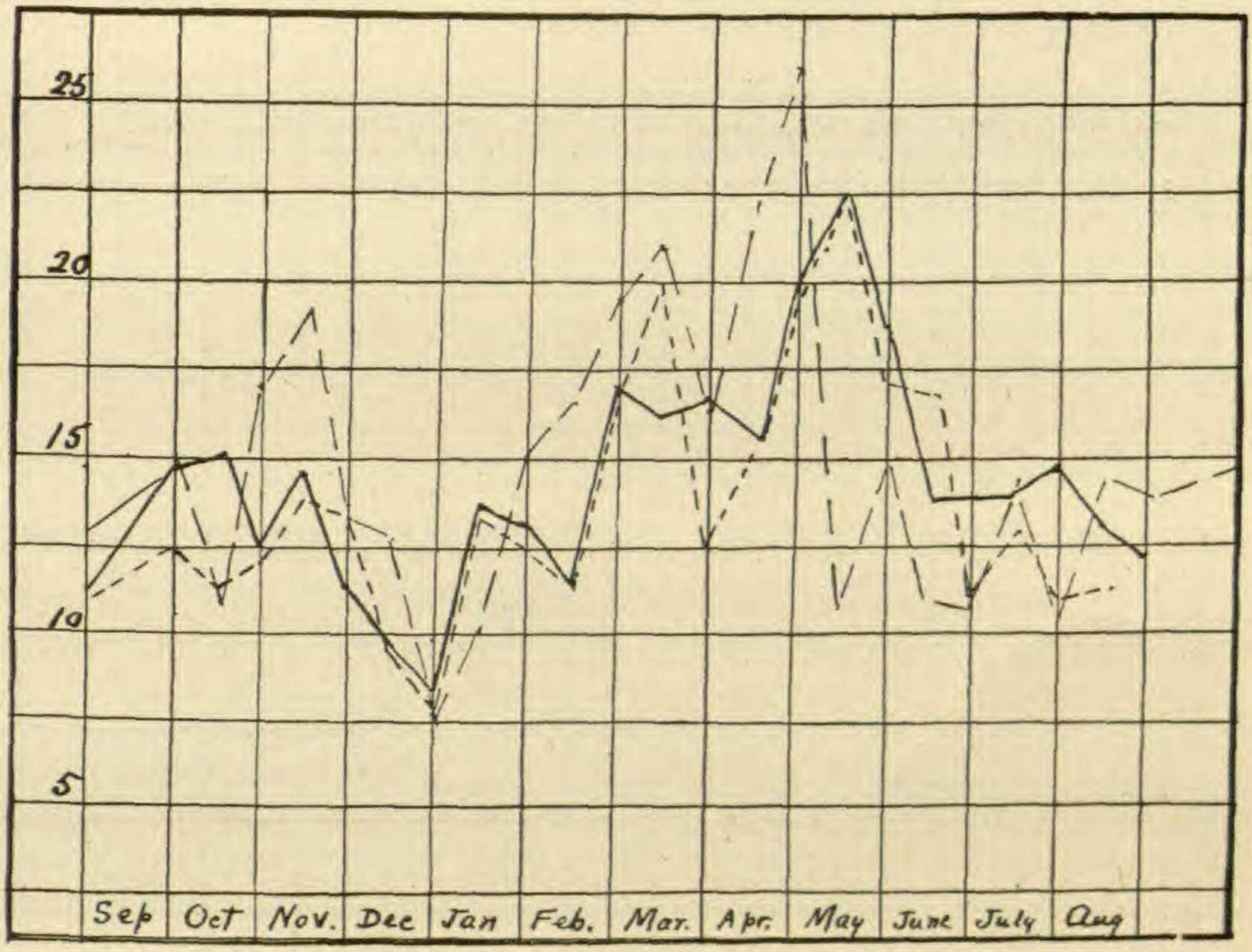

FIG. 1.—Chart showing comparison of yearly range of evaporation in Spanish oak-post oak forest (dotted line); short-leaved pine forest (heavy line); grazed beech forest (broken line).

about the same minimum. The actual minimum was 7.39 cc. in late December, and the actual maximum 27.97 cc. in early May. This forest, therefore, does not show such wide variation for the seasons as do the others given, and the curve representing the years' averages runs more evenly for this forest than does that of any other except the flatwoods. This evenness may be related to the fact that, although the trees are deciduous, their leaves, after dying and turning brown, remain on the branches most of

the winter; and as they are coriaceous in texture and more or less coated with felt on the under surface, they remain intact until the time for the new foliage. The low summer rate (as compared, for example, with the long-leaved pine rate) also may have a relation to the fact that although there is an absence of shrubs or undergrowth of importance, these trees are dwarfed or scrub-like, and the foliage grows low on the trunks; when growing closely they make a thicket-like forest.

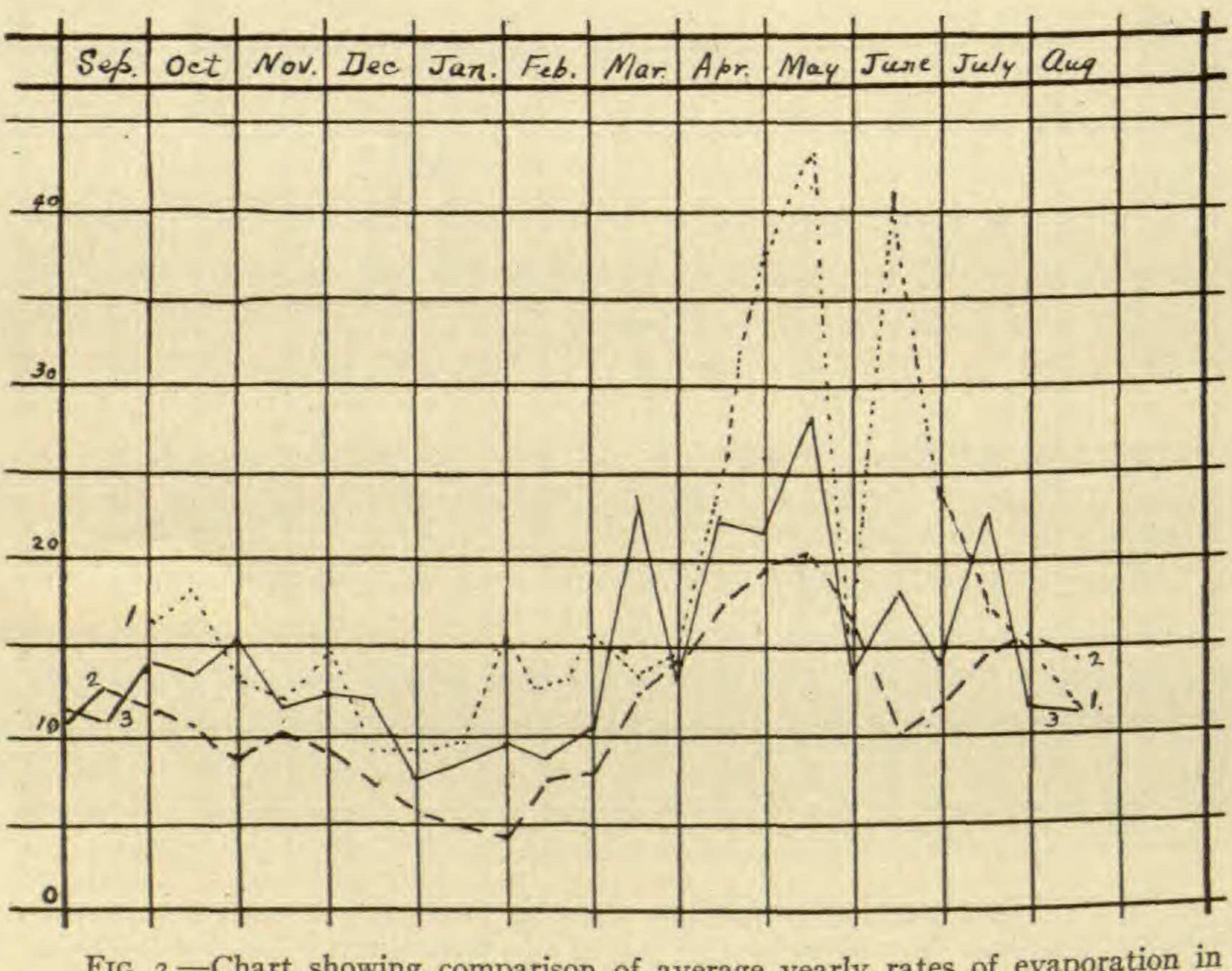

FIG. 2.—Chart showing comparison of average yearly rates of evaporation in scrub oak forest (heavy line); flatwoods (broken line); long-leaved pines on dry land (dotted line).

Station no. 6, in the dry pine wood, gave the average evaporation per day of 17.9 cc.; 12.28 cc. for the period January to May; 18.25 cc. for the summer period; 19.2 cc. for the winter period; with minimum monthly average of 8.9 cc. in December and a maximum of 32.5 cc. in April. The actual minimum was 4.15 cc. and the maximum 56.19 cc., showing the widest range of any station (fig. 2).

The flatwoods station, on Leon Sand, gave an average for 18 months (with a break in the record for December and January 1912–1913) of 12.99 cc. per day. The January to April average for 1913 is not complete, but for the summer and winter periods the averages are, in order, 13.24 cc. and 11.17 cc. The minimum month is January, 5.94 cc. per day; the maximum in May is 19.8 cc. per day. The actual minimum falls lower than that of any other, being 3.88 cc. in February, and the maximum was 25.44 cc. in May.

The meadow stations were not in operation for a long enough time to give results covering a year. From October to June the willows averaged 12.47 cc. daily, comparable to the flatwoods station. The average for the birch station for the time was 13.98 cc. daily. Their minima occurred in January and maxima in May.

Arranging the stations in the order of their yearly averages of evaporation, beginning with that having least evaporation, their order is as follows: hammock climax forest, willow (meadow) zone, flatwoods, birch (meadow) zone, Spanish oak-post oak forest, short-leaved pine forest, scrub oak forest, beech wood (open and grazed), long-leaved pine forest. Omitting the meadow stations, the others arranged in order of increasing rates are (for the summer period June to November), after the hammock forest, the Spanish oak-post oak forest, the flatwoods, the beech (grazed), the short-leaved pines, the scrub oaks, and long-leaved pines. The order, by winter average rates, is flatwoods, short-leaved pines, scrub oaks, Spanish oak-post oak, beech (grazed), and long-leaved pines. The order during the critical period of the year, from January to May (a dry period and a time of sharply rising temperature, corresponding to the time of vernation of the deciduous trees and of changes of leaves, in part or altogether, of many evergreens), is as follows: mesophytic hammock forest, Spanish oak-post oak forest, beech wood (grazed), short-leaved pine wood, long-leaved pine wood, and scrub oaks. Of these the order of the forests on the clayey soils of the upland is essentially that observed for their succession, the difference in winter being in the place of the leafless Spanish oak-post oak forest as compared with the conifer forest. In the pine and oak forests on the dry sandy soils, the same relation

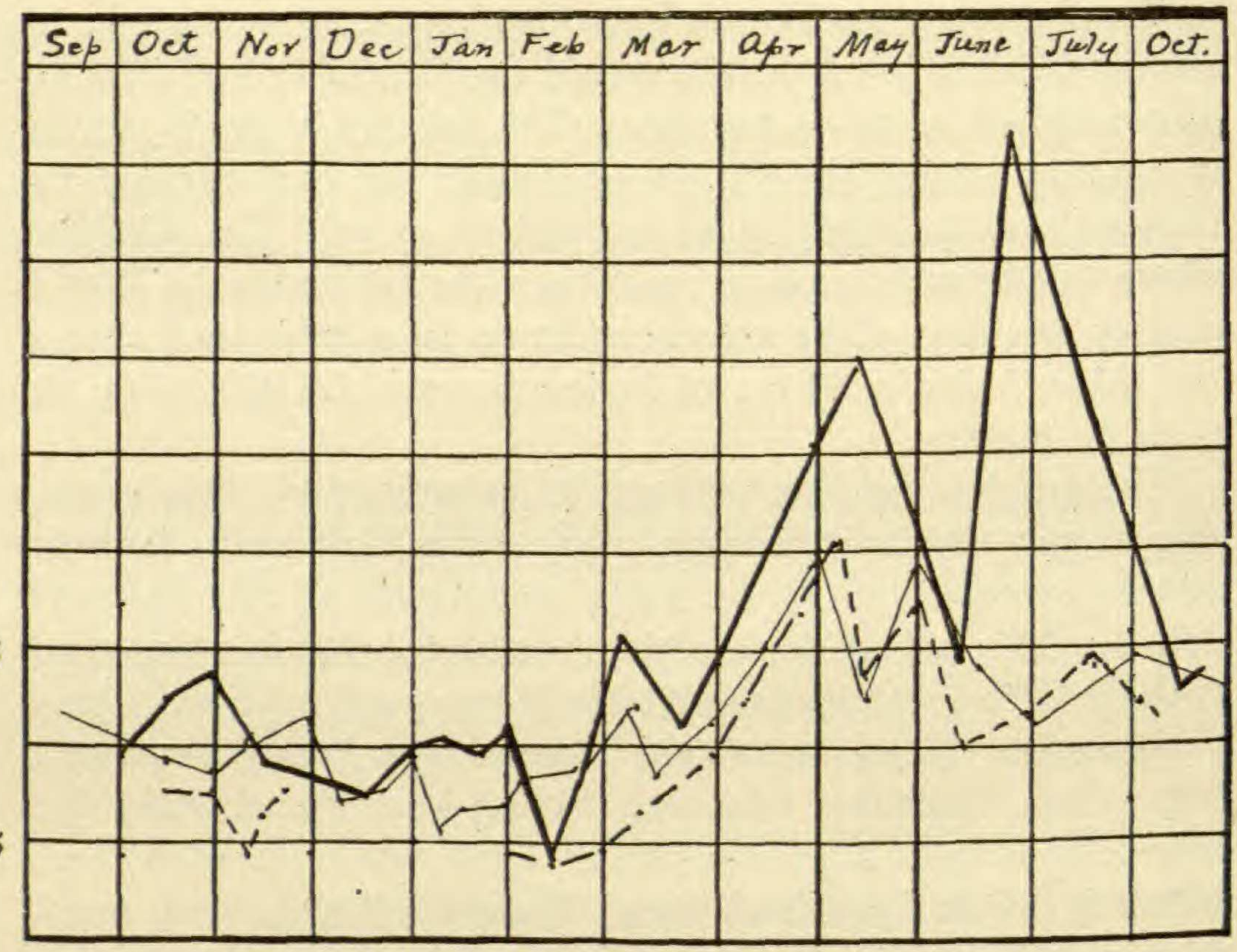

FIG. 3.—Chart showing evaporation rates of 3 pine forests: long-leaved pine on dry sand (heavy line); long-leaved pine on wet sand (broken line); short-leaved pine (light line).

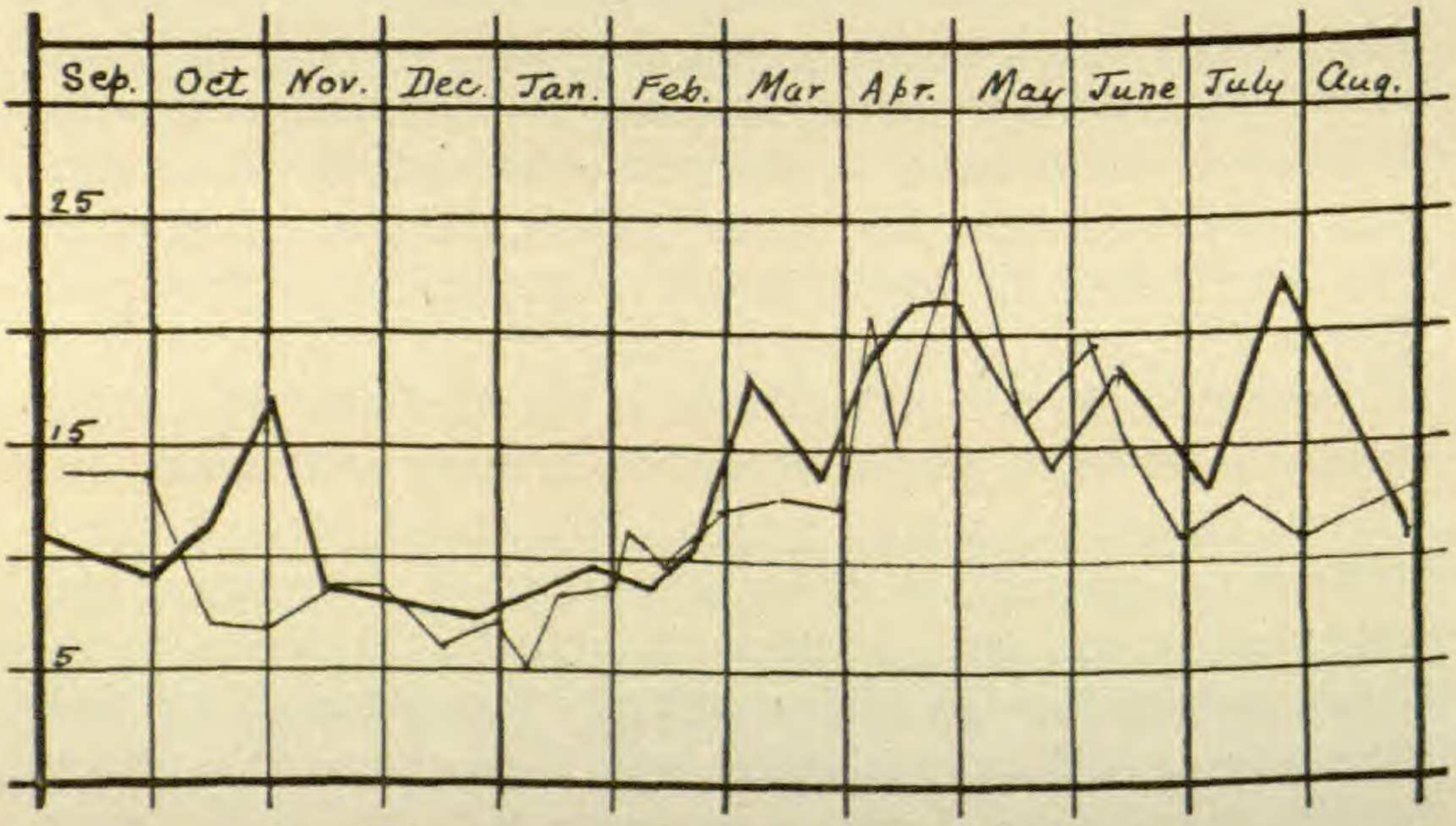

FIG. 4.—Chart showing comparison of evaporation rates, during same year, in the 2 oak forests: scrub oaks (heavy line); Spanish oak-post oak forest (light line).

holds, the oaks showing a higher winter rate than the pines. The two pine forests (short-leaved and long-leaved) on dry soil are nearest together in their evaporation rates during the spring. A comparison of the three pine associations and the two oak associations as charted will show these relations (figs. 3, 4).

The Leon Sand forest is singular in that it is so directly related to the soil moisture, and although all other factors tend to make the evaporation excessive, the constant humidity near the soil surface of the ground, owing to the soil saturation, modifies the curve until it is the most equable of any of those described in this report.

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